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HOME RANGE, MOVEMENT, AND NESTING OF LEAST BITTERNS IN WESTERN NEW YORK

HEIDI E. BOGNER[1,2,3] AND GUY A. BALDASSARRE

ABSTRACT.—We studied the nesting ecology of Least Bitterns (*Ixobrychus exilis*) during 1999 and 2000 within an 8,000-ha wetland complex in western New York. We used radio telemetry to track 33 adult Least Bitterns to locate nests and determine movement patterns, and 12 chicks to determine postfledging movements. Least Bittern Mayfield nest success rates were 43.8% (n = 38) in 1999 and 52.5% (n = 35) in 2000, and they renested and had double broods. Mean home range of adults was 9.7 ha (n = 33), but varied (range = 1.8–35.7 ha) depending upon whether birds used one or two areas during the breeding season. The mean movement of chicks from their nests was 13.4 m between capture and 23 days posthatching (n = 11), and 29.4 m when 24–27 days old (n = 4). Mean age at first flight was about 29 days old (n = 4). Vegetational structure and composition and marsh size appear to be important factors to consider when managing for Least Bittern populations. *Received 15 August 2001, accepted 23 April 2002.*

Research on the breeding biology of the Least Bittern (*Ixobrychus exilis*) has focused on nesting habitat, reproductive success, nesting behavior, and demographic characteristics (Kent 1951, Weller 1961, Frederick et al. 1990, Ziebell 1990, Post and Seals 1993, Post 1998, Rodgers and Schwikert 1999, Lor 2000). However, there still are significant gaps in our knowledge of this secretive marsh bird. For example, there is no information on Least Bittern home range and movement during the breeding season (Gibbs et al. 1992a), yet such information is necessary to determine habitat size and distributional requirements. Gibbs et al. (1992a) also noted the lack of information on the ability to renest and on juvenile dispersal patterns. Several researchers (Kent 1951, Weller 1961, Ziebell 1990; C. R. Paine unpubl. data) have suggested that Least Bitterns renest (initiate a new nest and clutch after a previous nest is unsuccessful) and have double broods (produce a second nest and clutch after a first clutch has hatched), but there has been no conclusive evidence from marked birds.

Finally, Least Bittern chicks (a bird between hatching and first flight) first leave their nest when between 5 and 9 days old, but they continue to return to the nest area for several days (Nero 1950, Weller 1961). Hence, because Least Bittern chicks are very mobile at a young age and are difficult to monitor because they use dense vegetation (Rodgers and Schwikert 1999), little is known about their postfledging movements. In this study, we define fledging as when the chicks are no longer predictably associated with their nest area (>5 m away), which usually occurred between 12 and 18 days old.

These gaps in knowledge are especially significant because the Least Bittern is listed by the U.S. Fish and Wildlife Service as a Species of Management Concern (U.S. Fish and Wildlife Service 1995) and has a state listing ranging from indeterminate to threatened in 9 of 13 northeastern states (Gibbs and Melvin 1992). The Least Bittern currently is listed as threatened in New York State. Hence, more information on many aspects of Least Bittern breeding biology clearly is needed to facilitate the design of appropriate management and conservation plans.

We used radio telemetry to track individual birds to examine aspects of Least Bittern breeding biology that have not been studied in detail. Our main objectives were (1) to calculate nesting success and determine if Least Bitterns renest or have double broods, (2) to determine home range and general movement patterns during the breeding season, and (3) to determine postfledging chick movements and age at first flight. We also provide information on other aspects of Least Bittern

[1] SUNY College of Environmental Science and Forestry, Syracuse, NY 13210, USA.

[2] Current Address: New York State Dept. of Environmental Conservation, 207 Genesee St., Utica, NY 13501, USA.

[3] Corresponding author; E-mail: hebogner@gw.dec.state.ny.us

breeding biology and natural history, including clutch size and nesting habitat.

STUDY AREA

We studied Least Bitterns between late April and late August, 1999–2000, within an 8,000-ha wetland complex in western New York composed of the Iroquois National Wildlife Refuge and the Oak Orchard and Tonawanda state wildlife management areas. The complex is located in the northern part of the Least Bittern breeding range (Gibbs et al. 1992a) in the Great Lakes Plain ecozone of New York State (Andrle and Carroll 1988), about 27 km south of Lake Ontario and 56 km east of Lake Erie (43° 07′ N, 78° 22′ E). This wetland complex consists of 60% wetlands (including 17% emergent marsh, 26% flooded timber, 12% open water, and 5% scrub-shrub marsh) and 40% grasslands, forests, early successional forests, or fallow fields (Lor 2000).

We conducted trapping and subsequent tracking and nest searching at eight emergent marshes: Oxbow (57 ha; 45% emergent vegetation, 55% open water), Goose (45 ha; 70% emergent vegetation, 30% open water), Paddy 1 (20 ha; 50% emergent vegetation, 50% open water/flooded timber), Paddy 2 (23 ha; 75% emergent vegetation, 25% open water), Ruddy (140 ha; 65% emergent vegetation, 35% open water), Olson South (12 ha; 45% vegetation, 55% open water), Cayuga (148 ha; 40% vegetation, 60% open water), and Knowlsville (19 ha; 35% vegetation, 65% open water). Ratios of emergent vegetation to open water are visual approximations we made during August 2000 from marsh edges and from a canoe. The dominant emergent vegetation in all marshes was cattail (*Typha* spp.). Other types of emergent vegetation included bur-reed (*Sparganium* spp.), hard-stemmed bulrush (*Scirpus acutus*), swamp loosestrife (*Decodon verticillatus*), and purple loosestrife (*Lythrum salicaria*).

METHODS

Trapping and radio attachment.—We trapped 57 of 70 (81%) adult Least Bitterns by broadcasting the male "cooing" vocalization (Bent 1926) from a tape recorder placed at water level in the center of a row of mist nets. We obtained vocal recordings from either the Peterson field guide series *More birding by ear: eastern/central* (Walton and Lawson 1994) or *Stokes field guide to bird songs: eastern region* (Elliot et al. 1997) and created 1-min continuous loop tapes with alternating periods of about 15 s of calling and 15 s of silence. Within a marsh, we usually operated 1–2 set-ups, each consisting of 1–6 nets and a tape player. We sometimes targeted individual birds by setting nets where a male was observed calling.

We also trapped 11 adult Least Bitterns (17%) by setting up 2–8 nets in a "U" shape around one end of a stand of vegetation and having 3–8 people walk through the vegetation to flush birds into the nets. We also hand captured two females on their nests. For all birds captured, we measured wing chord, beak length, and tarsus, and we weighed, determined sex via plumage color (Gibbs et al. 1992a), banded, radio marked, and released them at the trap sites.

During 1999, we fitted 2.28-g radio transmitters (Advanced Telemetry Systems, Isanti, MN) onto the backs of Least Bitterns between the wings by using either epoxy attached to the feathers (18 birds) or cyanoacrylate glue (super glue) attached to the skin (7 birds). We also attached radio transmitters to 12 birds by sewing and gluing the radio transmitters to a Herculite-laminated fabric (Herculite Protective Fabrics Corp., New York) bib fitted around the bird's neck under the chest feathers (Brininger 1996).

During 2000, with the exception of one radio transmitter attached with super glue, we attached 2.36-g radio transmitter packages between the wings on each bird's back with a stainless steel anchor-shaped wire inserted subcutaneously as described by Pietz et al. (1995). We modified the procedure by using super glue instead of sutures to hold the radio transmitter in place. Hence, the anchor simply was threaded through an incision made via a hypodermic needle, super glue was applied to the base of the radio transmitter, the radio transmitter was pressed onto the skin for several seconds until the glue dried, and a drop of super glue was used to seal the incision. It was not necessary to trim any feathers around the attachment site. Radio packages in both years never exceeded 3.5% of body mass.

Overall handling time of birds once removed from nets usually was ≤15 min. All trapping and handling followed the Ornithological Council guidelines (Gaunt and Oring 1997) and an Animal Welfare Protocol Statement at the State Univ. of New York, College of Environmental Science and Forestry.

We captured chicks between 12 and 18 days old by searching the vegetation surrounding nest sites. During 1999, we only banded chicks, but during 2000 we equipped one chick that weighed >65 g from each of 12 nests with a 1.3-g radio transmitter; radio transmitters never exceeded 2% of a chick's current body mass. We attached radio transmitters between the wings by applying a drop of super glue to the surface of the radio transmitter and holding it against the skin. Care was taken not to glue the radio transmitter to feathers. Chicks usually were handled for ≤10 min and released near their nest.

Nesting.—To locate nests, renests, and second nests, we homed on radio-marked Least Bitterns found in the same general location ≥5 days in a row. We also conducted nest searches in areas where radio-marked Least Bitterns were suspected of nesting. Nest searches were conducted by 1–5 people systematically wading back and forth through the marsh within about 3–10 m of each other. We marked nests with flagging tied to the tallest piece of vegetation within a few meters of the nest. We determined approximate hatching dates by floating eggs (Hays and LeCroy 1971), and we checked nests every 1–9 days to determine their fate. We determined nest initiation dates by backdating from hatching, assuming an incubation period of 19 days (Weller 1961). We recorded the vegetation used

for nest construction for most nests. For most nests located during 1999, we also recorded water depth under the nest and distance to the closest water pool ≥3 m in diameter.

We used the Mayfield method (Mayfield 1961, 1975) to calculate daily survival, nest success (for the period when eggs but not chicks were in the nest), and fledging success (for the period after the first egg hatched until the first chick was 12 days old). We chose 12 days because chicks began to leave the nest area at 12 days posthatching, and it became difficult to determine if an absence of chicks near the nest site meant chicks had left the nest area or were dead. We calculated standard errors and 95% confidence intervals, and performed tests to compare daily mortality rates using methods developed by Johnson (1979).

Home range and movement of adults.—We located radio-marked adult Least Bitterns 5–7 times per week by using triangulation with 3-element hand-held Yagi antennas. Consecutive locations on a single bird always were ≥12 h apart, following the protocol of White and Garrott (1990). To assure accuracy, observers in contact via 2-way radio simultaneously took compass bearings when both received clear signals and the bearings were at approximately right angles from each other and as close to the bird as possible. Over the course of 2-week periods, we monitored locations evenly during 2-h time blocks from 05:00–07:00 and from 22:00–05:00 EST.

We tested for observer error by placing additional radio transmitters in marshes used by radio-marked Least Bitterns. Observers took compass bearings of these radio transmitters from existing stations, using the same techniques used in routine tracking, except there were no discussions of radio transmitter locations via 2-way radio, and no movement to other stations if signals were unclear due to radio wave reflection or diffraction (Samuel and Fuller 1994). All technicians who participated in the radio telemetry portion of the study were tested.

The mean absolute angular error of 128 bearings was 8.3° ± 0.6 SD after eliminating extreme outliers (angular errors >25°, $n = 11$) (Lee et al. 1985). We eliminated these outliers because such errors were highly unlikely during actual data collection due to the use of the 2-way radios and ability of observers to move when signals were unclear or there was strong reflection or diffraction of radio waves (Samuel and Fuller 1994). The mean antennae-to-animal distance (AAD; Gould and Jenkins 1993) of a random sample of 35 bird locations was 191.9 m. When we used the mean angular error and the mean AAD, the mean estimated distance error from plotted to actual transmitter location was 27.9 m. When we used the methods from Lee et al. (1985) and White and Garrott (1990), bias was −0.5°, and the mean 95% confidence bearing arc (±1.96 SD) was ±20.4°. The mean 90% error polygon determined from two error arcs intersecting at right angles at mean AAD from two stations was 2.1 ha.

We calculated bird location coordinates using the program LOCATE II (Nams 1990), and we estimated home range for individuals via the fixed kernel method (Worton 1989) of the animal movement extension to ARCVIEW (Hooge et al. 1999). We used least squares cross validation to automatically select the bandwidth (smoothing parameter). We used the cross-validated fixed kernel home range estimator because it is the most accurate; Seaman and Powell (1996) found that the cross-validated fixed kernel home range was better than the harmonic mean estimator, which Boulanger and White (1990) found to be the least biased of the common home range estimators, including Fourier series, harmonic mean, minimum convex polygon, and two different 95% ellipse home range estimators. We calculated both the 95% utilization distribution, which we refer to as "home range," and the 50% utilization distribution, which we refer to as "core range." Calculations were done only on individuals with ≥30 locations (Seaman et al. 1999).

We also examined movement patterns by constructing plots of locations by date. The maximum distance between any two locations also was calculated for each bird using the animal movement extension to ARCVIEW (Hooge et al. 1999).

To examine differences in marsh size between sexes for home range, core range, and maximum distance between locations, we divided birds into four groups according to their sex and whether they were in marshes or groups of marshes >100 ha, or in relatively isolated marshes <60 ha. We chose these size categories based on the size distribution of marshes in the complex. Individual marshes were considered grouped if only a narrow dike separated adjacent marshes. In contrast, relatively isolated marshes <60 ha were still in the overall marsh complex but were separated from other marshes by more than a narrow dike (≥50 m distance and with barriers such as roads, tree rows, forested areas, or fields). There were three relatively isolated marshes <60 ha (57, 45, 19 ha) and two marshes or groups of marshes >100 ha (Group 1 included three individual marshes of 148, 12, and 4 ha that were used by radio-marked Least Bitterns; Group 2 included four individual marshes of 140, 20, 23, and 12 ha also used by radio-marked Least Bitterns, and two marshes of 142 and 20 ha that were not used by radio-marked Least Bitterns).

Using the Shapiro-Wilk test (Conover 1980), we determined that home range, core range, and maximum distance between locations data were not normally distributed even after a $\log_{10}$ transformation. We therefore used Mann-Whitney 2-sample tests (Conover 1980) to test for differences between males and females (with marsh sizes combined), and among marsh sizes (with sexes combined) for home range, core range, and maximum distance among locations. We also used Mann-Whitney tests to examine differences in home range, core range, and maximum distance between two locations for females in the two marsh size categories, males in the two marsh categories, males and females

TABLE 1. Reproduction estimates of Least Bitterns at Iroquois National Wildlife Refuge and Tonawanda and Oak Orchard state wildlife management areas wetland complex, western New York, in 1999 and 2000.

	Year	Number of successful nests	Number of failed nests	Exposure days	Daily survival		Nest success	95% confidence interval (%)
					Mean	SE		
Nest success	1999	27	9	320.5	0.972	0.009	58.2%	40.4–83.2
	2000	24	6	296.5	0.980	0.008	67.8%	49.3–92.9
Fledging success	1999	23	4	174	0.977	0.011	75.6%	57.0–99.7
	2000	23	5	237.5	0.979	0.009	77.5%	61.5–97.1
Overall success	1999	25	13	494.5	0.974	0.007	43.8%	27.6–69.0
	2000	24	11	534	0.979	0.006	52.45%	35.5–77.2

in marshes <60 ha, and males and females in marshes or groups of marshes >100 ha.

Movement of chicks.—We located radio-marked chicks by homing on their radio signal every 3–7 days after capture to determine the distance from their nest. To minimize chick disturbance, we usually approached no closer than 5–10 m. If a chick was in the same location on two consecutive checks, however, we approached it until we could determine if the transmitter had detached or the bird had died. If a chick reached flight stage and left the nest area, we monitored its location using triangulation from the marsh edge. We monitored chicks until either their radio transmitters fell off, the signals were lost, or until 31 August.

RESULTS

Trapping.—During 1999, we radio marked 36 adult Least Bitterns (16 males and 20 females). The largest number of adults (12) was trapped in Oxbow Marsh, followed by 3–6 adults trapped at six other marshes. The majority of the radio transmitters fell off (including all radio transmitters attached with epoxy); thus, only nine birds were radio tracked long enough to obtain ≥30 locations. We recaptured two of the 36 adults later in the same season, both females.

During 2000, we radio marked 32 adults (17 males, 15 females). Eight adults were captured in both Oxbow Marsh and Ruddy Marsh, followed by 2–6 trapped in five other marshes. We tracked 24 adults long enough to obtain ≥30 locations. We recaptured one male trapped earlier in 2000, but we did not recapture any birds banded in 1999. We also radio marked 12 chicks.

Nesting.—We found 51 nests during 1999 and 41 nests during 2000 that contained chicks, eggs, or egg fragments. During both years, the largest number of nests was found in Oxbow Marsh (1999: 15 nests; 2000: 17 nests), followed by Ruddy Marsh (1999: 11 nests; 2000: 9 nests). Other marshes contained 1–9 nests. During 1999, we found nests of four radio-marked birds (two male and two female, including one pair). During 2000, we located 14 nests of radio-marked males and 9 nests of radio-marked females. We observed a radio-marked male copulating with a female on their nest, which contained an incomplete clutch of two eggs.

Mean clutch size was 5.25 eggs ± 0.11 SE (range: 3–6, $n = 64$). There were 30 nests with 6 eggs, 23 with 5, 8 with 4, and 3 with 3. The time from laying the first egg to hatching the first egg ranged from 19–21 days ($n = 5$ nests).

Of the total nests located during 1999 and 2000, the majority (77%, $n = 84$) were constructed exclusively of cattail, but nests also were made from bur-reed (13%), bur-reed and cattail (4%), grasses and cattail (2%), hard-stemmed bulrush (1%), swamp loosestrife (1%), and purple loosestrife (1%). Water level at nest sites during 1999 ranged from 0–57 cm with a mean of 34.4 cm ± 2.1 SE ($n = 33$). The mean distance to open water from nest sites was 3.5 m ± 0.8 SE ($n = 36$). Nest initiation began in early May and continued until early July during 1999, and began in mid-May and continued until mid-July 2000.

Fledging success was higher than nesting success during both 1999 and 2000 (Table 1), but the longer period for nest success (19 days) than for fledging success (12 days) can account for this result. Daily survival rates for the two periods were not significantly different (1999: $Z = 0.348$, $P = 0.73$, 2000: $Z = 0.659$, $P = 0.95$). The combined overall suc-

TABLE 2. Movements of radio-marked Least Bitterns at Iroquois National Wildlife Refuge and Tonawanda and Oak Orchard state wildlife management areas wetland complex, western New York, were small but highly variable in 1999 and 2000.

	Core range (ha)		Home range (ha)		Maximum distance between two locations (m)	
Group	Mean	SE	Mean	SE	Mean	SE
All adults	1.4	0.3	9.7	1.5	393	35.7
Males	1.0	0.3	8.1	2.2	307	34.8
Females	1.8	0.5	11.4	2.1	485	56.0
Marshes <60 ha	1.1	0.3	7.5	1.5	360	53.5
Marshes >100 ha	1.6	0.4	11.6	2.4	421	48.3

cess rates for the 31-day period were 43.8% during 1999 and 52.5% during 2000. We attributed most nest failures to predation, although we also suspected some nests were deserted, and at least one nest was destroyed by strong winds.

During 2000, we observed both renesting and double brooding. In one instance we observed a radio-marked individual (male 713) on one nest, and after that nest was depredated, on a second nest. In two instances of double brooding we observed two radio-marked individuals (male 913 and female 942, not a pair) on first nests, and after those nests hatched, on second nests. We suspect two additional instances of renesting (male 892 and female 752, not a pair) and two additional instances of double brooding (female 831 and male 733, not a pair) because we observed radio-marked individuals on first nests and we subsequently flushed them from the immediate vicinity of different nests. The mean time between failure or hatching of the first nest and initiation of a new nest was 5.3 days ± 0.9 SE (n = 3) for renesting birds, and 21.7 days ± 3.5 SE (n = 3) for double-brooding birds. The mean distance separating the two nests was 106.8 m ± 38.2 SE (n = 3) for renests and 213.6 m ± 94.1 SE (n = 4) for double broods.

Home range and movement of adults.—We obtained 1,407 locations for 33 adult Least Bitterns (17 males and 16 females). Least Bitterns usually did not leave the marsh where they were trapped unless there were adjacent marshes separated only by a narrow dike. In the Tonawanda State Wildlife Area, where several marshes were separated only by dikes, we detected 12 of 15 birds (80%) moving among marshes at least once. In contrast, there were only two separate incidents in which birds from relatively isolated marshes <60 ha were detected moving from the marsh where they had been trapped.

Mean home range size was 9.7 ha ± 1.5 SE (range = 1.8–35.7 ha, n = 33), and mean core range was 1.4 ha ± 0.3 SE (range = 0.2–8.0 ha, n = 33; Table 2). Overlapping home ranges were common. In Oxbow Marsh, for example, home ranges of four radio-marked males and three radio-marked females overlapped. The mean home range of adult females was 3.3 ha larger than that of adult males (Mann-Whitney U = 81.00, P = 0.049). Least Bitterns in marshes or groups of marshes >100 ha had a larger mean home range than Least Bitterns in marshes <60 ha, but the difference was not significant (U = 104, P = 0.27; Table 2). None of the other home range and core range parameters were significant: core range of males and females (U = 88.00, P = 0.87), core range and marsh sizes (U = 110, P = 0.38), females by marsh size categories (home range: U = 24.00, P = 0.44; core range: U = 30.00, P = 0.88), males by marsh size categories (home range: U = 26.00, P = 0.42; core range: U = 19.00, P = 0.13), males versus females for relatively isolated marshes <60 ha (home range: U = 14.00, P = 0.12; core range: U = 14.00, P = 0.12), and males versus females for marshes or groups of marshes >100 (home range: U = 25.00, P = 0.20, core range: U = 31.00, P = 0.46).

The mean maximum distance between two locations for all adults was 393 m ± 36 SE (range = 172–801 m, n = 33; Table 2), but this distance was 179 m longer for females

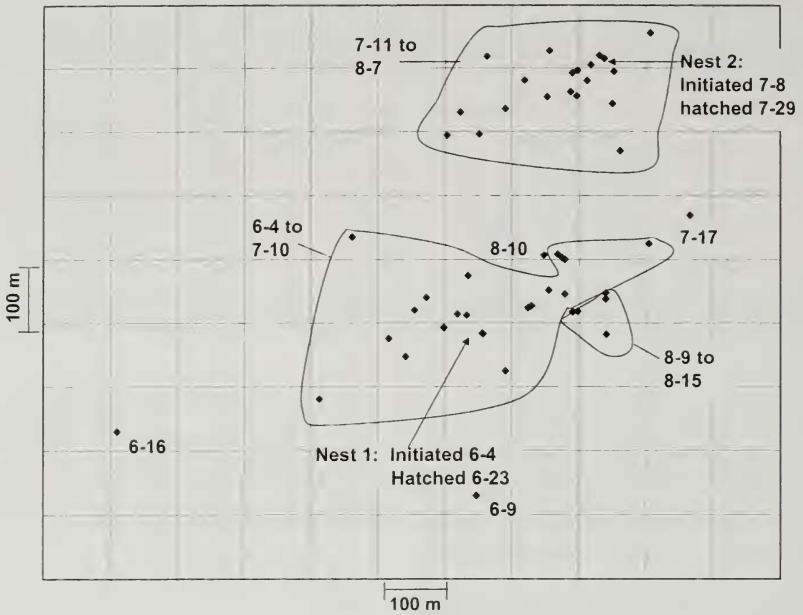

FIG. 1. Least Bittern male 733 was double brooded and used two distinct areas in Ruddy Marsh, Tonawanda State Wildlife Management Area, western New York. Locations were from 4 June to 15 August 2000; home range = 29.7 ha and maximum distance between two locations = 718 m.

than for males (U = 77.00, P = 0.034). In addition, maximum distance between two locations was 123 m longer for males in marshes or groups of marshes >100 ha than for males in relatively isolated marshes <60 m (U = 13.00, P = 0.033).

The shape of home ranges and the movement among Least Bitterns varied markedly. Six birds (15%) each used two distinct areas during the breeding season. For example, male 733 was double brooded with a nest in each of two areas of Ruddy Marsh (Fig. 1). The remaining birds were located primarily in one area, but the size of these areas varied greatly. For example, all the locations for male 782 were close to his one nest (home range = 2.6 ha); male 913 had two successful nests 29.3 m from each other in a single cattail clump (home range = 5.5 ha); and male 792, with one verified nest, used one large area (home range = 13.7 ha). Females 942 and 752 (each had two nests) used one general area but shifted use over time from one part of their range to another (Fig. 2). About 50% of females initially moved either within one marsh or among marshes before settling into one area for the remainder of the season (Fig. 3), and 39% of birds made at least one trip away from their usual home range areas.

Movement of chicks.—Of 12 chicks fitted with radio transmitters, six lost their radios before attaining flight. Another chick was depredated at 19 days of age (we found the carcass). One fledgling was not included in the calculations because its age at capture was not known. Of the remaining four birds, mean distance from nests was 13.4 m ± 1.8 SE (n = 11) between capture and 23 days posthatching. Between 24 and 27 days of age, chicks wandered ≤60 m but the mean distance from their nests was only 29.4 m ± 10.5 SE. At this stage, chicks could move quickly through vegetation, but they probably were not yet able to fly. Age at first flight for individual birds could not be determined exactly because birds were not monitored on a daily basis, but the approximate mean age of the four birds retaining radio transmitters at first flight was 29 days. They initially made short flights within the marsh where they hatched, and then three of five left the

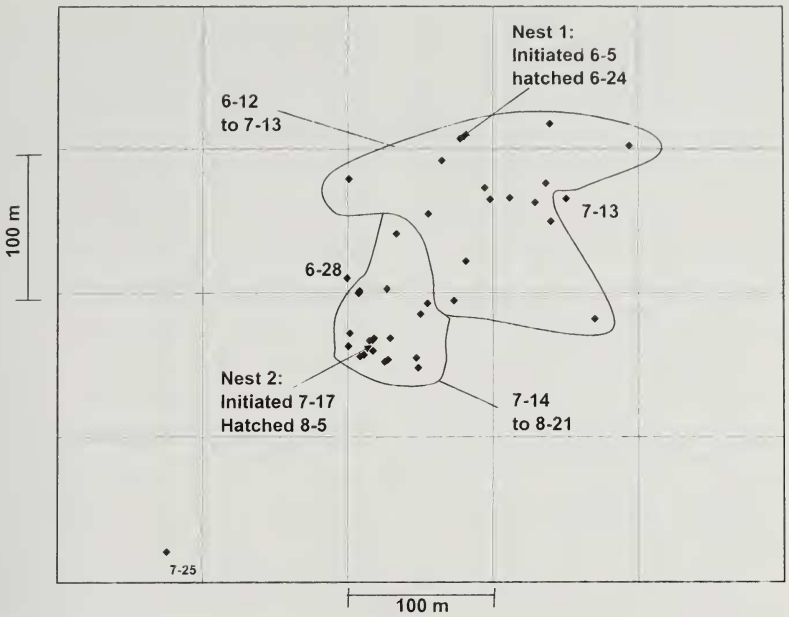

FIG. 2. Least Bittern female 942 was double brooded, used one general area, but shifted use within that area in Oxbow Marsh, Oak Orchard State Wildlife Management Area, western New York. Locations were from 12 June to 21 August 2000; home range = 2.8 ha and maximum distance between two locations = 203.7 m.

marsh ≤8 days of first flight. The two remaining birds lost their radios shortly after first flight. We were able to relocate only one bird after leaving its natal marsh. This bird was flying within its natal marsh when 27–28 days old, but at 30–31 days had traveled 1,800 m to another marsh. When 37–39 days old, we observed this bird standing on a stick in shallow (<10 cm) water in an area of sparse cattail mixed with purple loosestrife and flooded timber.

DISCUSSION

During the 2000 field season, we did not recapture any of the 48 Least Bitterns trapped during 1999, which suggests either low return rates or low survival. There have been documented returns of other marsh birds, such as the American Bittern (*Botaurus lentiginosus*) (Brininger 1996, Azure 1998) and the Virginia Rail (*Rallus limicola*) (Mousley 1931), to the same breeding areas, but there is no information on philopatry in Least Bitterns (Gibbs et al. 1992a). More intensive trapping of birds for several years likely is required to examine philopatry in Least Bitterns.

Nesting.—The relatively large mean clutch size of 5.25 eggs and the large percentage of 6-egg clutches (46.9%) we documented suggests latitudinal variation. Mean clutch size was 4.08 eggs ± 0.59 SD in Florida (n = 104; Rodgers and Schwikert 1999), 3.80 eggs ± 0.78 SD in South Carolina (n = 110; Post 1998), 4.39 eggs ± 0.43 SD in Iowa (n = 59; Weller 1961), and 4.6 eggs ± 0.76 SD in Wisconsin (n = 35; Ziebell 1990). No clutches larger than five eggs were observed in either South Carolina (Post 1998) or Florida (Rodgers and Schwikert 1999). Increasing clutch size with latitude may be explained by Ashmole's hypothesis (Ashmole 1963, Ricklefs 1980), which suggests that clutch size is determined by the ratio of available resources during the breeding season to the demand for these resources by breeding adults.

Consistent with other studies (Weller 1961, Ziebel 1990, Post and Seals 1993, Lor 2000), we found that the majority (83%) of Least Bittern nests were at least partially constructed from cattails. Bur-reed (17% of nests) and hard-stemmed bulrush (1%) were

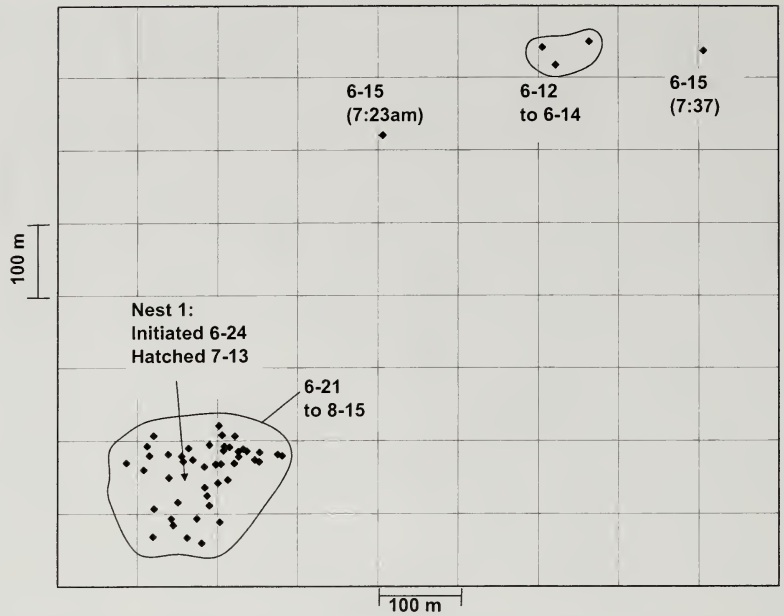

FIG. 3. Least Bittern female 173 moved around for a week before settling into one area where she had one nest in Goose Marsh, Oak Orchard State Wildlife Management Area, western New York. Locations were from 12 June to 15 August 1999; home range = 7.9 ha and maximum distance between two locations = 792 m.

used to a lesser extent than cattail, probably at least partially due to differences in availability, but Rodgers and Schwikert (1999) found soft-stemmed bulrush (*Scirpus validus*) was used for construction of 52% of nests (n = 207) in Florida, and Kent (1951) found most nests in Iowa were located either in bur-reed (58%) or soft-stemmed bulrush (37%; n = 19). In Florida, Kushlan (1973) and Frederick et al. (1990) found that sawgrass (*Mariscus jamaicensis*) was an important nesting substrate. Frederick et al. (1990) suggested that the main reason Least Bitterns usually are found in cattail in northern states is because cattail is among the few tall plants in the North to grow in high densities in deep water.

Our nest success rates were 58.2% in 1999 and 67.8% in 2000. Other studies of Least Bitterns reported Mayfield nest success estimates of 80% (n = 16) and 46% (n = 37) in the same study area as ours (Lor 2000), 37% (n = 49) in Illinois (C. R. Paine unpubl. data), and 54.9% (n = 159) in South Carolina (Post 1998). Least Bitterns often nest over water and away from shore, making them less vulnerable to land predators. However, there still are numerous potential predators of Least Bittern young and eggs, including American Crows (*Corvus brachyrhynchos*), raptors, blackbirds, Blue Jays (*Cyanocitta cristata*), snakes, and turtles (Bent 1926, Weller 1961), and raccoons (*Procyon lotor*; Ziebell 1990). As in other studies (Ziebell 1990, Lor 2000), Marsh Wrens (*Cistothorus palustris*) were suspected egg predators because of the small puncture holes found in some eggs during our study. We also suspected that some nests were depredated by mink (*Mustela vison*).

Our study is the first to confirm instances of renesting and double brooding in Least Bitterns based on marked individuals, although more information is needed to determine the proportion of birds that renest or have second broods. Our study suggests that a minimum of 17% (3 of 24) of Least Bitterns produced double broods and 60% (3 of 5) renested. Second nests were not necessarily near first nests: one renest was 165 m from the first nest, and another was 475 m distant.

Home range and movement.—Although our

radio telemetry error was relatively high when determining the location of individual Least Bitterns, the level of accuracy was adequate to determine the approximate home range and movement patterns. Actual error probably was not as high as that determined from error testing because observers had the ability to move to a new station if signals were not clear, and they could discuss the location of birds via two-way radio. In addition, because the antennae-to-animal distance almost always was small, the effect of degree error was small (estimated mean = 29.7 m).

Adults.—The mean home range size of Least Bitterns was only 9.7 ha. One possible factor contributing to small home range size is that Least Bitterns seem to feed primarily in the area surrounding their nest. For example, Weller (1961) observed Least Bitterns catching prey items from their nests as they incubated, and hunting in the water surrounding their nest. We observed many cases of vegetation bent over to form a feeding platform in dense cattail clumps that also contained Least Bittern nests. By gripping emergent vegetation and using these feeding platforms, Least Bitterns are able to feed over deep water near their nests (Gibbs et al. 1992a). Other small marsh birds have even smaller home ranges. For example, home range estimates for Sora and Virginia Rails were 0.2 ha (Johnson and Dinsmore 1985), and a home range estimate for Pied-billed Grebes (*Podilymbus podiceps*) was 1.3 ha (Glover 1953). The American Bittern uses similar freshwater wetland habitat as the Least Bittern, but has much larger home ranges (mean breeding home range = 210 ha; mean postbreeding home range = 183 ha; Azure 1998). This larger home range probably is a result of the male American Bittern not incubating eggs or caring for young, nests that sometimes are located in upland cover adjacent to wetlands (Gibbs et al. 1992b), its larger body size (mean male weight = 906 g, n = 28; mean female weight = 580 g, n = 17; Brininger 1996), and greater food requirements.

The large variation in Least Bittern home range size (1.8–35.7 ha) may have been influenced by birds using two distinct areas during the breeding season. For example, the three largest home ranges belonged to males 733 (29.7 ha) and 762 (31.6 ha), and female 843 (35.7 ha); all used two distinct areas during the breeding season. Whether birds use two areas or stay in one area could depend upon factors such as food availability, nesting substrate, and whether they produce double broods.

Both home range and maximum distance between locations were larger for females than males, a difference likely due to the stage of the breeding cycle when birds were trapped. Due to the nature of the trapping method (using broadcasts of male vocalizations), males most likely were trapped while defending an established nesting territory, whereas females (except those captured on nests) probably were trapped while in search of a mate. Therefore, perhaps some females were located in a number of different locations before they settled into an area. In some cases, Least Bitterns may spend a large portion of the breeding season in search of a mate. For example, a female trapped in Oxbow Marsh on 29 May, and then again 20 days later in Goose Marsh, was responding to the broadcast of a male call.

Overall, marsh size was not associated with home range size or maximum distance between two locations. Differences may not have been significant, however, because the marshes in the <60 ha marsh category were not very small (19–56 ha). The only significant difference related to marsh size was that males in marshes or groups of marshes >100 ha had a greater maximum distance between locations than males in the isolated marshes <60 ha. This finding may be a result of males in larger marshes having a larger area for foraging and being able to initiate second nests farther from initial nests. Brown and Dinsmore (1986) and Gibbs et al. (1991) found that both marsh size and isolation were important factors determining bird species richness in wetlands. In particular, Brown and Dinsmore (1986) suggested that Least Bitterns possibly were area dependent because 92% of Least Bitterns were observed in marshes ≥5 ha. Lor (2000), in the same study area as ours, found that although Least Bitterns were detected in marshes of all three size categories (1–41 ha, 41–100 ha, 101–155 ha), they were more abundant in marshes 41–100 ha than in marshes 1–41 ha. She at-

tributed this finding, however, primarily to the vegetation composition and structure in Oxbow Marsh, which was in the 41–100 ha category and where Least Bitterns were particularly abundant.

Vegetation type and cover ratios likely are even more important than marsh size for Least Bittern populations. This wetland complex has a large overall population of Least Bitterns, probably in large part due to the many marshes with a high level of interspersion of water and tall, emergent vegetation (primarily cattail). For example, Oxbow Marsh, which had the highest number of nests found and the most birds trapped, was composed of clumps of dense cattail surrounded by open water with an approximate interspersion of 45% emergent vegetation to 55% open water. Weller and Spatcher (1965) found that Least Bitterns nested only in sturdy emergents over water and reached their highest numbers in hemi-marshes (50% water to 50% cover). In fact, they observed that Least Bitterns did not use an area of dense vegetation at all until muskrats (*Ondatra zibethica*) removed considerable vegetation to create a hemi-marsh condition. Weller and Spatcher (1965) also observed maximum bird density and diversity in hemi-marshes, and Gibbs et al. (1991) found that wetlands in Maine with an intermediate level of emergent cover (33–66%) were used by more species than wetlands with cover levels of either >66% or <33%. Nelson and Kadlec (1984) synthesized considerable information on the hemi-marsh concept, noting that attractiveness to birds may relate to production of invertebrates through the growing season.

Chicks.—Similar to Nero (1950), we found that Least Bittern chicks first left the immediate vicinity of their nest when 12–18 days old. When 24–27 days old, they were located a mean distance of 29 m from the nest. Although chicks probably are fed by their parents until able to fly (Palmer 1962), a certain degree of dispersal from the nest area before flight likely is an adaptation to limit predation of all offspring from a nest.

Whereas adult Least Bitterns were not found far from the marsh where they were trapped, three of five birds that retained radio transmitters until capable of flight left their natal marsh within 8 days of first flight. Young Least Bitterns may disperse because they require different types of habitat for foraging than their nest areas can provide. For instance, areas with shallow water may provide easier, more efficient foraging for young birds; the one bird that was relocated after it left its natal marsh was observed standing in water <10 cm deep. Fledgling movements in other bird species may serve to assess possible future breeding sites and to aid in muscle development (Reed and Oring 1992), both of which also could be true of Least Bitterns.

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